Report for 2002SC4B: Renovating Water for Conservation and Reuse: Developing DesignParameters for Constructed Wetlands for Domestic Wastewater Treament and Mitigation

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Report Follows:

Renovating Water for Conservation and Reuse: Developing Design Parameters for Constructed Wetlands for Domestic Wastewater Treatment and Mitigation

Statement of Critical Regional or State Water Problem.

Water resources such as Lake Keowee in northwestern South Carolina are both precious and fragile. Although this resource appears to be plentiful to much of the public, more people are recognizing limitations during the current persistent drought. This resource is used widely for purposes ranging from drinking (domestic supply) and fish and wildlife to primary and secondary contact recreation and industrial supply. Although the reservoir, Lake Keowee, is the least eutrophic large lake in SC, its current water quality is typical of much of the waters in the Southeastern US in terms of alkalinity, hardness, conductivity and pH.

Lake Keowee is an 18,372-acre impoundment of the Keowee River, with a maximum depth of approximately 155 feet (47 meters) and an average depth of approximately 54 feet (17 meters). The lake's watershed is comprised of 273 square miles (707 km) in NC and SC. From the time of the original study of water quality in this reservoir (Rodgers 1974) to the present, dramatic changes in land use in the watershed have led to heightened public concerns regarding water quality and the future of this resource. Mandated by the Clean Water Act (CWA – Section 303d), recent evaluations of tributaries indicated that nutrients and fecal coliforms are primary constituents of concern in terms of impairment of this water resource for designated uses. These constituents and problems are widespread and a critical need is a reliable and cost-effective approach to mitigate their downstream impacts on water resources in the watershed. Constructed wetlands have been used in a number of situations as part of integrated management strategies to conserve and reuse water and are scientifically defensible, cost-effective and sustainable solutions for these water quality problems.

Statement of Results or Benefits.

The potential benefits of this project are numerous and widespread. The most obvious is provision of a reliable technology for resolving persistent and pervasive water quality problems in watersheds (i.e. fecal coliforms and nutrients). Conservation of limited water resources is another benefit of this project. The results from this study will empower citizens and water resource managers with requisite knowledge to assume responsibility for water quality in watersheds on a local basis. If these systems perform as expected, the potential benefits in terms of tourism and fisheries (especially in the coastal areas of SC) are enormous.

Nature, Scope, and Objectives of the Research.

Nature of the Research. Although constructed wetlands have been used widely for wastewater renovation (Huddleston et al. 2000, Carleton et al. 2000, Kurnaidie and Kunze 2000, Hawkins et al. 1997, Kadlec and Knight 1996, Kent 1994, Moshiri 1993), we still do not have data for design parameters that are dependable and site independent. These data will be crucial as we apply this technology to mitigate adverse impacts on downstream biota and to achieve water reuse for irrigation, groundwater recharge, aquaculture and wildlife habitat. In fact, a recent publication by

the U.S. EPA (U.S. EPA 2000) acknowledged that although hundreds of thousands of dollars had been spent assembling a database from constructed wetlands for domestic wastewater treatment, such an approach is inadequate for development of design parameters. There is a critical need for reliable site independent design parameters that can be tailored for a site–specific design based upon targeted constituents and reasonable transfer and transformation kinetics. The proposed research will provide a comprehensive evaluation and an approach for technology transfer to other sites in SC and the U.S.

Scope of the Research. We propose to develop the design parameters that would permit installation of an appropriately designed and sized constructed wetland treatment system to treat domestic wastewater at a variety of sites. There are considerable but avoidable risks associated with constructing and implementing treatment wetlands that are inaccurately designed or sized (undersized or oversized). The proposed design parameters will be site independent (i.e. independent of latitude, longitude and altitude) and will be based in sound theory and fundamental principles such as the Laws of Thermodynamics. Information regarding both kinetics (rates) and extent of transfers and transformations is needed to successfully produce a site-specific design. In previous research, we have used first order estimates of kinetics coupled with performance results from pilot-scale studies to produce reliable full-scale designs (e.g. Huddleston et al. 2000). Since domestic wastewater should vary significantly only in flow (rate or volume) and concentration (or strength), but not in primary constituents of interest from site to site (Metcalf & Eddy 1991), it is entirely logical that we could develop accurate design parameters without expending time and resources on a pilot study for each site. We have applied this approach with considerable success to industrial wastewaters such as pulp and paper that do not vary widely in primary constituents (Hudddleston et al. 2000). However, we will use pilot-scale systems (Hawkins et al. 1997) for this research in order to efficiently vary input parameters (i.e. domestic wastewater strength or concentration [primary and secondarily treated] and flow rates). Experiments will test hypotheses regarding seasonal (temperature) dependence of rates of transfers and transformations of targeted constituents (Manios et al. 2000, Noah 2001). Both laboratory and nursery (field) experiments will evaluate and confirm the suitability of the treated water for reuse.

Objectives of the Research. The objectives of the proposed research are: 1) to design, construct and monitor the performance of a full-scale constructed wetland and analogous pilot-scale model constructed wetlands for tertiary treatment of domestic wastewater for reuse; 2) to measure kinetics and performance of specifically designed constructed wetlands to remove nitrogen, phosphorus and coliforms from secondary and primary treated wastewater; and 3) to characterize the outflow water from the constructed wetland treatment systems in terms of its suitability for reuse for golf course irrigation or for plantings for shoreline erosion control, wildlife and power line right-of-way beautification and enhancement. An allied objective that will be accomplished as a result of this research will produce site independent design coefficients and parameters that will assist successful transfer of this technology to other sites. Results will be published in peer-reviewed journals and presented at regional meetings and workshops.

Timeline of Activities. Construction will be accomplished in the first two months of this project. Monitoring will begin after one month of acclimation. Results for warm or hot months will be obtained in the first six months of the project and results for colder month will be gathered in the following four months. Monitoring will continue through to the end of the project. Data will be analyzed continuously and manuscripts will be prepared for submission to journals for peer review in the final month of the project. As opportunities arise, results will be presented at regional meetings and workshops.

Methods, Procedures, and Facilities.

Methods and Procedures. The design of the full-scale constructed wetland has already been accomplished and was contributed by Roy F. Weston, Inc. (Atlanta, GA office, Mr. Doug Mooney, P.E.). The design has recently been approved for construction by the S.C. Department of Health and Environmental Control and bidding for construction has begun with construction to be initiated and completed in the next two months. The construction site is located in the gated community of Keowee Key near their domestic wastewater treatment facility for ~1000 people. We have full cooperation and support of the engineering firm (Roy F. Weston, Inc.) and the Keowee Key management and families (especially Mr. Bob Peterson of Keowee Key Utilities who is the certified and licensed operator of the wastewater treatment facility). Basically, the full-scale constructed wetland treatment system will receive secondarily treated wastewater from the existing treatment system. The full-scale constructed wetland will consist of approximately one acre of *Typha latifolia* planted in a low nutrient, sandy hydrosoil. The constructed wetland will be lined with compacted clay to prevent treated water communication with groundwater. Water depths and flows in the constructed wetlands will be controlled by "stop logs" and valves, respectively. The outflow from the full-scale constructed wetland can be introduced into Lake Keowee or diverted for irrigation purposes. Detailed blueprints of the design of this constructed wetland as well as the Conceptual Design Document are available on request. This full-scale constructed wetland was specifically designed for tertiary treatment of secondarily treated domestic wastewater. Monitoring of targeted constituents will demonstrate the performance of this system. Parameters that will be measured in both inflow and outflow samples include: TN, NH_3, NO_3, TP, Ortho-P, BOD_5, COD, TSS, fecal coliforms and *E. coli.* In addition, laboratory toxicity testing will be conducted on these water samples using *Ceriodaphnia dubia* and *Pimephales promelas* as recommended by the U.S. EPA. Weather parameters will also be continuously monitored using NOAA approved instrumentation (both instruments and assistance provided by Dr. Dale E. Linvill of Clemson University's Department of Agricultural and Biological Engineering). As mentioned above analogous pilot-scale experiments will also be conducted to develop rate coefficients and design parameters. Water reuse suitability experiments will also be conducted on the treated waters.

Facilities. We have full cooperation and collaboration of the Keowee Key wastewater treatment facility and will base the field experiments at that secure location. We have adequate laboratory analytical, aquatic toxicology and microbiological facilities in our modern 38,000 square foot building for the laboratory analyses. For the water reuse suitability experiments, we have access to field sites as well as greenhouse space.